IDAHO

DEPARTMENT OF FISH AND GAME

Jerry M. Conley, Director

USE OF DEMAND FEEDERS FOR REARING FINGERLING

RAINBOW TROUT

by

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ABSTRACT

Rainbow trout averaging 30/lb (4.5") were reared on demand feeders for 5.5 months and feed conversions were compared with otherwise identically treated hand-fed fish. Conversions of demand-fed fish were consistently lower, thus indicating more efficient metabolic transformation of food to fish flesh. Several important disadvantages which may limit the usefulness of demand feeders are also discussed:

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INTRODUCTION

Improvement of fish rearing methods is an important factor in reducing hatchery operation costs. Short of an unlikely drop in feed prices, one way to lower those costs would be to reduce feeding levels while, at the same time, maintaining optimal growth and health.

We installed demand feeders at Mackay Hatchery for the main purpose of releasing our labor force from the extensive time required for hand feeding. During the course of this program, we established control (hand-fed) and experimental (demand-fed) groups and closely monitored feed dispensed and pounds gained for rainbow trout fingerlings in four ponds, two demand-fed and two hand-fed. This report summarizes the results of those investigations.

OBJECTIVES

Determine and compare feed conversions for rainbow trout fingerlings fed either by hand or on demand feeders and investigate possible reasons for any observed differences in growth.

TECHNIQUES USED

Materials

Demand feeders were constructed from 6-gallon plastic buckets mounted on 2x4 frames which spanned the width of the pond (Fig. 1). The feeder frame unit was built at an approximate cost of $15 per unit--16 units were used in this experiment. The "activator" consisted of a 36" length of heavy gauge wire (or welding rod) suspended from a threaded wire affixed horizontally inside the bucket (two nuts on the inside held the activator in place). The activator was suspended through a 1" diameter hole (feed port) and projected about 8" below the water surface. A rubber stopper (size 12) was centrally pierced and threaded onto the activator, positioned about 3/4" below the bottom of the bucket--vertical adjustment enabled dispensing of smaller or larger feed particles, respectively, and also controlled the amount of feed released when the activator was struck. The feeder was operated by fish striking the submerged end of the activator, thus jarring the stopper and releasing feed through the feed port. In the initial stages of the study, only one feeder per section (100' x 8') was required, but later on it was necessary to install two feeders per section to supply a day's ration. Fish distribution in the ponds required that feeders be located in the upstream half of the section: low oxygen levels (60% saturation) at Mackay may have been responsible for fish congregating in the upper half. We found that feeders placed in the lower half were not utilized by a large majority of the fish. Fish required from two days to a week to become fully acclimated to the feeders--this process was facilitated by reducing hand feeding during the start-up period.

OVERHEAD VIEW

INFLOW

feed exit port (1" dia.)

bucket
(w/ lid removed)

threaded wire

nuts

6-gallon buckets

nuts

pond wall

activator
(between nuts)

POND (1 section)

2x4 planks
(2" dimension up)

walkboards

SIDEVIEW (cutaway)

feed

wire
activator

2x4

rubber
stopper

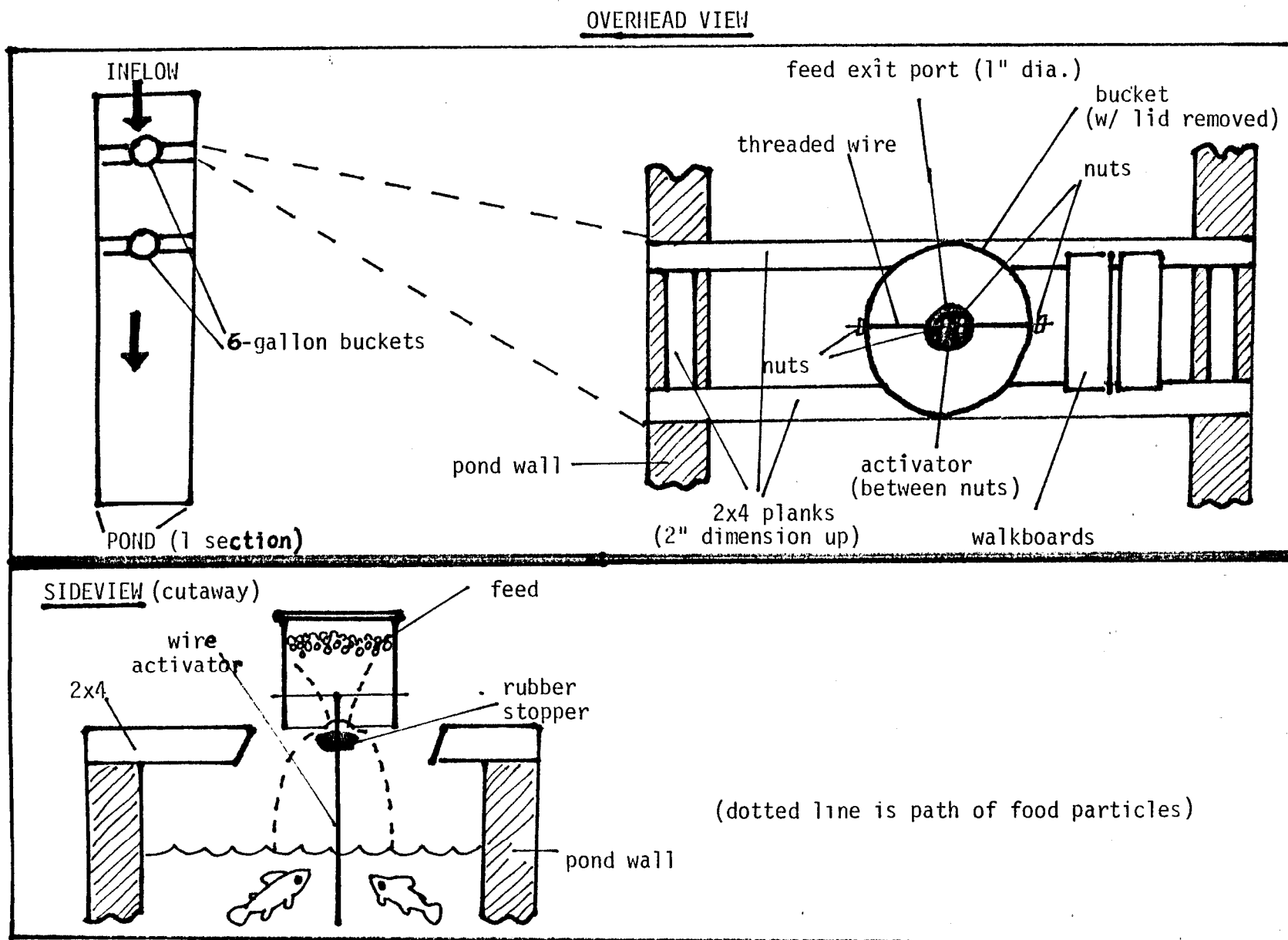(dotted line is path of food particles)

pond wall

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Fig. 1. Schematic of demand feeder (Ponds 4 & 5).

Feeding Regime

We started fingerling rainbow trout (Trout Lodge, Washington) on feeders on November 1, 1981, at an average of 30 per pound, and when the experiment ended five months and two weeks later on March 16, 1982, they had reached five per pound. All fish were fed Rangen's dry trout and salmon feed beginning with 5/32 coarse crumbles and ending with 5/32 pellets cut-short. Hand-fed fish were fed at a rate of two to three percent of body weight, depending on size (Rangen's Feed Chart). During hand feeding, we practiced standard broadcasting methods to obtain optimal feed dispersion and minimize wasted feed.

Pond Parameters

Four cement raceways (ponds) were used, two for the control group (hand-fed) and two for the experimental group (demand-fed). Each pond consisted of four sections (100' x 8' x 3' ea.) separated by dam boards--fish were initially placed in the upstream section and were later split into lower sections for thinning. Water discharges varied somewhat from pond to pond and could not be manipulated so,to take into account any effect on growth due to different flow rates, we established both high and low discharge ponds for each group (Table 1). Photoperiod, temperature (52^0F), dissolved oxygen (4.5 ppm), natural food sources (insects, etc.) and other environmental variables were either known or could be safely assumed to be similar in the four ponds.

Discharge was measured using a Cipoletti weir and volume was obtained from pond dimensions and average actual water depth. Volume divided by discharge yielded water turnover rates (T):

$$\text{Turnover} = \frac{\text{volume (V)\_(gal.)}}{\text{discharge (Q)(gal./min.)}} \quad \frac{\rule{3cm}{0.4pt}}{\text{(in minutes)}}$$

Exchange rate (R) (Clary 1979) was derived from T:

$$\text{Exchange} = \frac{60}{T} \text{ (in turnovers per hour)}.$$

The approximate volume of one section was 10,000 gallons (1300 ft^3) with R ranging from 7 to 11, depending on discharge (Table 1).

Biotic Parameters

Fish densities were similar in all ponds and were periodically re-adjusted in the normal course of thinning the fish. Density (lbs/gal) was figured on the basis of the total number of fish per section--38,000 fish per pond originally stocked minus estimated mortality--divided by the number of fish per pound:

Table 1. Environmental parameters in demand-fed and hand-fed ponds. V = volume (gal), Q = discharge (gal/min) (where Q not shown it is same as previous value), R = exchange rate (turnovers/hr), D = density (lbs/gal).

Pond	Nov.				Dec. 1			Jan. 18				Feb. 28			Mar. 16		
		Q	R	D	V	R	D	V	Q	R	D	V	R	D	V	R	D
3	10,200	1200	6.9	0.11	20,000	3.5	0.67	20,000	1365	4.1	2.25	48,022	1.7	0.60	48,022	1.7	0.90
4 (Demand)	10,200	1400	8.2	0.11	21,000	4.0	0.82	21,000	1365	3.9	2.44	48,960	1.7	0.90	48,960	1.7	1.10
5 (Demand)	9,260	1600	10.3	0.12	19,500	5.0	0.76	19,500	1235	3.8	3.31	47,460	1.6	1.00	47,460	1.6	1.10
6	9,260	1650	10.7	0.14	18,750	5.5	0.68	18,750	1235	3.9	2.85	47,550	1.6	0.80	47,550	1.6	1.00

$$\text{Density (D)} = \frac{\text{total pounds (P)}}{\text{volume (V)}} \quad \text{(in lbs/gal)}$$

$$\text{where P} = \frac{\text{number of fish (\#)}}{\text{pound count (\#/lb)}}$$

Pound counts were taken every two weeks on one-pound or five-pound random samples, depending on size. Mortality rates were similar in all ponds over the study period and averaged less-than 1% per month.

Conversions were calculated from data on feed consumed (actually fed) and pounds of fish flesh gained per tally period:

$$\text{Conversion (C)} = \frac{\text{total feed consumed per period per pond}}{\text{total weight gained per period per pond}}$$

In addition to the above measurements, we also observed fish behavior (feeding vigor, distribution) and general appearance (size consistency, color, overt signs of disease).

FINDINGS

Prior to analyzing the results, any factors which could affect fish growth rates and thereby bias the interpretation of the data should first be examined. One such factor is density, which has been shown to influence growth and behavior (Fenderson and Carpenter 1971; Brauhn et al. 1976; Fagerlund et al., 1981). Our procedures for thinning fish and keeping densities approximately equal among comparison groups effectively eliminated this source of bias (Table 1).

Bias could also occur as a result of differences in water discharge and exchange rates due to the controlling effect of these factors on oxygen availability, flushing rate of metabolic waste and metabolic cost of swimming (i.e., higher R requires greater effort to maintain position in water). Any significant change in these parameters could affect growth (Wedemeyer et al. 1976; Brauhn et al. 1976). Examination of Table 1 shows that discharge (Q) and exchange rates (R) varied between ponds in the initial months (November through mid-January) but were similar for all ponds thereafter. During the initial months, conversions (C) also varied (Table 2), but no discernible correlation is apparent between fluctuations in Q, R and C. In sum, we can reasonably assume that inter-pond differences in the above factors--discharge and exchange rate--had a negligible influence on the observed differences **in** conversions.

Finally, other potentially biasing factors, such as photoperiod, temperature, water chemistry and availability of extraneous food items were equivalent in all ponds and are, therefore, eliminated as significant sources of bias.

Since any experimental bias derived from density and discharge effects have been examined and found to be insignificant, we conclude that feeding

Table 2. Conversions (lbs. food fed/lbs. gained) in demand-fed vs. hand-fed ponds. Initial size
          (no./lb.) is given at top left corner with final size in top right corner (brackets).

Pond #	1-Dec._ 1	Dec. 2---15	Dec.16-Jan. 18	Jan.19---31	Feb. 1---18	Feb. 19---28	Mar. 1---16
3	[33] 1.3 (840/634)	[21] 1.4 (783/555)	[16] 2.6 (1934/745)	[12] 8.2 (816/100)	[12] 0.8 (1532/2042)	[9] 1.2 (1160/1000)	[6] 0.9 (1400/1553)
4 DEMAND	[32] 0.6 (661/1076)	[17] 0.8 (460/605)	[13] 3.0 (1474/484)	[11] 0.7 (619/938)	[9] 1.1 (1026/915)	[7] 0.9 (768/835)	[5] 1.0 (1219/1205)
5 DEMAND	[32] 0.7 (654/929)	[18] 1.1 (453/414)	[15] 0.8 (1364/1613)	[9] 3.1 (613/197)	[9] 1.1 (969/920)	[7] 0.9 (739/840)	[5] 1.0 (1210/1211)
6	[28] 2.4 (915/387)	[22] 1.6 (816/513)	[17] 1.7 (2154/1282)	[10] 0.8 (918/1209)	[8] 1.8 (1764/1000)	[8] 1.9 (1160/623)	[6] 1.6 (1400/861)

SUMMARY

Pond #	Nov. 1----Mar. 16		
3	[33]	1.3 (8471/6629)	[6]
4	[32]	1.0 (6228/6058)	[5]
5	[32]	1.0 (5985/6123)	[5]
6	[28]	1.6 (9127/5887)	[6]

method, the only known and consistent difference between the ponds under study, very likely produced the observed differences in feed conversions. A comparison of total amounts of feed supplied and pounds gained over the study period shows that demand-fed fish ate less than hand-fed (12,213 vs. 17,589 lbs eaten) but grew as well as the hand-fed fish (12,181 vs 12,516 lbs gained).

Lastly, although we did not analyze fish behavior or health quantitatively, through close observation we noted several consistent trends: 1) there was a gradual loss of vigor, characterized by lethargic feeding behavior, in demand-fed fish but not in hand-fed fish; 2) demand-fed fish appeared to ride higher in the water and tended to crowd the tail-screen to a greater extent than did the hand-fed fish, but mortality rates for both groups were similar and were not abnormally high; 3) we noted considerably more uneaten feed on the bottoms of hand-fed fish but more accumulated feces in demand-fed ponds.

DISCUSSION

The efficiency of conversion of food into fish flesh is the measure most commonly used to quantitatively evaluate hatchery feeding programs (Piper et al. 1982). At Mackay Hatchery, hand-fed rainbow trout fingerlings were fed relatively more feed (based on standard feed chart schedules) yet experienced the same weight gain as did demand-fed fish, which ate less on an ad libitum feeding regime. Our available evidence strongly suggested that one factor alone--feeding method produced the observed differences in conversions. Better growth using demand feeders is a common finding (Patterson and Boydstun 1980; Statler 1982; Orr et al. 1982; Kuhn 1982). The observations we obtained also suggested possible reasons for better conversions on demand feeders as explained below.

The principle that fish, as well as most other animals, adjust their food intake according to energy needs can be described as one of those rare biological "truths." It follows from this premise that fish which consume less but maintain good growth (respective to fish which consume more yet have the same growth rate) probably have expended less energy for "non-growth" activities (swimming, fighting, etc). At this time, we lack firm data which would support the hypothesis that demand-fed fish actually expended less energy for non-growth activities but we obtained observations which strongly suggest that this may have been the case in these specific experiments. To wit, we consistently noted that hand-fed fish seemed to exert more effort **in** obtaining food (mass feeding frenzies followed by scavenging until the feed was rendered inedible by disintegration on the pond bottom) as opposed to demand-fed fish which appeared less active, at least during daylight hours. Our findings are supported by other investigators who have found a definite correlation between fish behavior and growth. Fagerlund et al. (1981) described lower growth rates in hatchery coho salmon (as contrasted to wild salmon) which he attributed to the elicitation of a low-level chronic state of stress brought about by "routine hatchery operations" (feeding, cleaning, visitors, handling,

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chemical treatments) which disrupt-the normal social organization "typical of" populations of juvenile salmon (Fenderson et al. 1968). We suggest that the elimination of some of these "routine" operations (i.e., mass feedings, overhead presence of human feeder), while being one of the practical advantages of demand feeders, might also coincidentally reduce stress and thereby enhance growth in the manner described by Fagerlund above.

The suggestion that hand-fed fish utilized feed less effectively and that this resulted in higher conversions is further supported by the following observations. We noted more uneaten feed on the bottoms of hand-fed ponds as well as a much higher incidence of post-feeding activity on the pond bottom. Moreover, demand-fed ponds generally contained more feces and needed to be cleaned more often. These two phenomena can be satisfactorily explained by examining the differences inherent in the two feeding methods employed: fish fed by hand may need to scavenge the pond bottoms as a result of the turmoil associated with mass feeding as well as the uneven spread of feed particles (even with the best of hand broadcasting methods), thereby stirring up bottom materials and promoting the flushing process. On the other hand, fish fed on demand feeders consumed small lots of feed at a time and apparently obtained all the feed particles before they sank, thus these fish did not aid the flushing process by scavenging and the ponds subsequently accumulated more detritus. The greater degree of observable turmoil and scavenging in hand-fed ponds suggest that these fish exerted more effort obtaining food than did demand-fed fish but did not necessarily obtain more nutrition for their effort, thereby possibly reducing their growth efficiency. Also, it is possible that valuable water-soluble nutrients (vitamins C and B) were leached from the feed during its dissolution on the bottoms of hand-fed ponds, thus adversely affecting the growth efficiency of hand-fed fish.

We consistently observed feed levels in hoppers to be greatly reduced in the morning although they were filled the previous evening, thus suggesting that feeding activity of demand-fed fish was concentrated during the evening period. Other investigators using demand feeders have noted similar behavior (Camenish, pers. comm.). Fish undergo a daily activity cycle with the dusk-dawn period being the peak of activity in many diurnal species--this phase has been correlated with a definite increase in the presence of drift organisms which comprise the fishes' natural diet (Chapman and Bjornn 1969). On the other hand, insect abundance is relatively low and predator vulnerability for fish is high during midday, thus creating a relatively unfavorable environment for feeding and survival. This situation would be especially relevant for fish being fed by hand in the "routine" hatchery situation, which can be stressful (for the fish) in itself. The predisposition of fish (allowed to feed voluntarily) to feed at times most favorable for their growth and survival is not surprising: demand feeders may simply allow fish to follow natural rhythms--whether or not this can affect fish growth is a matter of speculation.

In sum, our findings indicate that the use of demand feeders improved food conversions of rainbow trout fingerlings, resulting in optimal growth using less feed and thereby potentially reducing hatchery operation costs. In this study alone, comprising less than 6 months, approximately $1,250 in direct feed costs would have been saved had all four ponds been equipped with demand feeders, assuming an average $25 per 100 pounds of feed. In addition, as Patterson and Boydstun (1980) pointed out, demand feeders may prove advantageous where water supply is limited as well as allowing fish culturists to quickly detect when fish go off feed. However, wide-spread use of demand feeders may be constrained by certain problems such as impaired stamina of fish (particularly later in the feeding program) and the need for additional pond cleaning time. Moreover, demand feeders may not be appropriate in situations where fish will outgrow a limited rearing space or, for example, when salmon or steelhead smolts are close to optimal release size. Other investigators have also expressed concern about the unwanted development of excessive fat deposits in trout broodstock fed on demand feeders (Orr, pers. comm.). Lastly, while using demand feeders constructed according to the plans depicted in Figure 1, we found that care must be exercised to: 1) periodically remove stale feed at bottom of hopper, 2) check rubber stopper position to prevent excessive feed loss, and ⁻3) avoid moisture condensation inside hopper lid which promotes feed disintegration and spoilage.

RECOMMENDATIONS

Low-cost demand feeders are appropriate in situations where accelerated fish growth is desired or when budgetary constraints require cost reduction, primarily in labor and feed expenditures. However, in view of our findings suggesting inferior stamina of fish on demand feeders, removal of feeders prior to the occurrence of potential health or vigor problems is recommended, taking into account that these impairments may be manifested sooner at higher temperatures (above 52°C).

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